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# A COMPARATIVE STUDY ON SWARM INTELLIGENCE ALGORITHMS

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## ABSTRACT

Swarm Intelligence algorithms are meta-heuristic and population-based stochastic optimization algorithms. These algorithms are influenced by an intelligent and collective behaviour of insects or animals such as ants, fireflies, dragonflies, wolves, cuckoo, hawks etc. The behaviour of these insects and animals offers information and strategy to win the hunts in their own way. Their behaviour of hunting uses an optimised approach i.e. they win over their prey by using least number of hunting steps. The algorithms are developed on the basis of their behaviour to solve the real-world problems. This research paper presents a comparative study of various swarm intelligence optimization algorithms.

**KEYWORDS:** Swarm Intelligence algorithms, meta heuristic, nature inspired.

## INTRODUCTION

This paper presents various meta-heuristic, nature-inspired and swarm intelligence optimization algorithms like cuckoo search, ant colony, firefly, grey wolf, grasshopper, dragon fly, particle swarm, Harris hawks & bald eagle search. These meta-heuristic algorithms are very helpful in the optimization for solving various engineering, AI neural networks, computational and NP- hard problems. The nature inspired algorithm follows genetic pattern according to the breeds family of insects or animals. Swarm refers to a family of insects and intelligence refers to the social behaviour of those insects. The Clustering methods based on swarm intelligence are used in optimization challenges based on Particle Swarm, ant colony algorithms (Yashoda and Vrinda, 2022).

The cuckoo search algorithm is discussed by authors Yang & Deb (Yang and Deb, 2009) in their article. The behaviour of various insects or animals breeds like cuckoo, ants, flies, wolf, grasshoppers, and hawks inspires the further research done in swarm intelligence domain.

The intuitive behaviour of firefly optimization was given by Xin-She Xang in 2008 (Kumar, et.al, 2021). The firefly algorithm gives more valuable search in comparison to intermittent search strategy (Yang and He, 2013). The ant colony inspires to searching behaviour of food (goal) by ant species described by Dorigo et al in 1996. This algorithm works for routing and load balancing problems. The algorithm efficiently works for type of travelling salesman problems. This algorithm needs more parameters for computation of optimal paths (Dorigo, et.al, 2006). The Firefly optimization can efficiently achieve the global search and local search to increase the convergence rate with the hybrid Moth Flame Optimization (MFO) (Divyashree, et.al,2022).

The intuition of Grey wolf given by an author (Mirjalili, 2018). The hunting strategy of grey wolf optimizer (GWO) lives in a pack or group of 5-12 packs. They can work together in a pack. There is a pack leader. The pack waits for the prey to enter their territory. The hunting done in different ways are called Alpha, beta, delta, and omega respectively. They(wolves) search for the prey by themselves. This algorithm with the decision tree helps to analyse genome data in cancerous cells and image enhancing (Abualigah and Diabat, 2020). GWO is used in Intrusion Detection system (IDS) (Sasikumar, et.al, 2022) to classify the data efficiently for detection of various attacks and intrusions.

The grasshopper is a bug found in the natural, open environment and mostly in the fields of farmers. It is born from an egg and has two stages; in the first stage it lies inside a nymph and in the second stage reaches adulthood. The grasshoppers harm the harvest (Mirjalili, et.al,2018).

The hawks are smart birds that fly in the sky. They have cooperative behaviour. The way of hunting by hawks is very strange. The hawks perform exploration and exploitation search. They always keep eyes and wait for the hunt, and as soon as they see, pounce on them quickly. Harris Hawks Optimizer (HHO) works as a better solution optimizer (Heidari et al, 2019). The main idea is to mimic the action and reaction of Hawk's team collaboration hunting in nature & prey escaping to discover the solutions of the single objective problem.

The dragonflies reproduced the eggs in water. The dragonflies also have newbie and adult stages like grasshoppers. There are various variants that have been implemented for DA due to reliable features of the algorithm, that is why it is more flexible and scalable in solving problems (Alshinwan, et.al,2021).

The swarm particle moves like a sine wave motion. It does not ensure convergence for even global optima, the adopted procedures stuck in individual optima due to lack of diverse population of swarm particles. It is based on the moment & intelligence of swarms. Several swarm particles communicate either directly or indirectly with one another using search directions. During an iteration of PSO, each particle updates its position according to its previous experience and the experience of its neighbours. (Wang, et.al,2018). The word bald mean is white and bald eagle is the national bird of U.S.A. The bald eagle hunts the fishes. The way of considering the prey is very similar to HHO (Heidari A, Mirjalili H, et.al, 2019).

## 2. LITERATURE REVIEW

### 2.1. Cuckoo Search Algorithm

This algorithm is a meta-heuristic search optimization method inspired by cuckoo. Some cuckoo species lay their eggs in the nests of host birds if they discover the eggs are not their own eggs, either throw or simply abandon the old nest and build a new nest elsewhere. CSO works better than PSO. It possesses randomised moves in all dimensional spaces which give a global optimal solution. It easily falls into the local optimal solution and the slow rate of convergence. There are various variants for Cuckoo search in the area of optimization. It is used to solve Nurse scheduling problems, travelling salesman problems.

### 2.2. Firefly Algorithm

This algorithm based on unique flashing patterns, nature inspired metaheuristic, swarm intelligence and behaviour of fireflies. The fireflies moved or walked due to the attraction of light intensity of each other for communication. The light intensity represents their fitness function. The decrease in distance between two fireflies seems if their brightness of light is low. It means the brightness of fireflies are inversely proportional to distance among them. The fireflies of lower intensity approach higher intensity. The fireflies move randomly If they have the same intensity or brightness. The new position of fireflies was achieved by the random walk and communication of them. The random walk is done in steps. This algorithm is applicable in various engineering domains like solving nonlinear optimization problems, fake detection, feature selection, dynamic programming problems, antenna design, structural design etc. The firefly algorithm gives more valuable search in comparison to intermittent search strategy. Due to the attraction method of fireflies, it has a speedy convergence rate for global optimum but it lacks for local optimum.

### 2.3. Ant Colony Optimization Algorithm

This algorithm is a meta-heuristic algorithm, inspired by social behaviour of ants. The ants live at various places such as in tree roots, in soils, inside rooms, houses as well as outside that is in a colony. The ant species have their own way of traversing the path in discovery of foods. They influenced a chemical hormone called pheromones which works like a communication signal for their followers. All the ants leave the pheromones in their path while they travel and their colleague ants follow the same path. If one can reach the source of food, then all col-

league ants will reach there. The ant feels vibrations, touch, sound, and chemical signals since they have no ears. The ants walk in discovery of foods, but they first try the closest and shortest path. This method works to find optimal paths. This algorithm works for routing and load balancing problems. The algorithm efficiently works for type of travelling salesman problems. This algorithm needs more parameters for computation of optimal paths. Theoretical analysis is difficult. The sequences of random decisions are not independent. The probability distribution changes by iteration. The research is experimental rather than theoretical. The time to convergence uncertain but convergence is guaranteed.

**2.4. Grey Wolf Algorithm**

This algorithm is inspired by the hunting strategy of grey wolf. The Grey wolf (GW) lives in a pack or group of 5-12 packs. They can work together in a pack. There is a pack leader. The pack waits for the prey to enter their territory. The hunting done in different ways are called Alpha, beta, delta, and omega respectively. They (wolves) search for the prey by themselves. Select weakest prey. They hunt in a cooperative way. The algorithm with the decision tree helps to analyse genome data in cancerous cells. The algorithm works for image enhancing.

The Grey wolf gives low solving accuracy, bad local searching ability and slow convergence rate. The main drawback of GWO is the low capability to handle the difficulties of a multi-modal search landscape, as it seems that all three alpha, beta and gamma wolves tend to converge to the same solution. Adding more random components to mutate the solutions during optimization will increase the chance of finding a global optimum when solving challenging multi-model problems. The GW optimization achieved due to three types of implementations are seek, encroachment and attack over the prey. [12] For predicting continuous values of parameter, support vector regression (SVR) methodology is used in many areas of machine learning. The SVR method is optimized by GWO with BES for achieving the prediction and accuracy of convergence.

**2.5. Grasshopper Algorithm**

This meta-heuristic algorithm comes under the category of swarm intelligence behaviour and Inspired by foraging. The grasshopper is a bug found in the natural, open environment and mostly in the fields of farmers. It is born from an egg and has two stages, in the first stage it lies inside a nymph and in the second stage reaches adulthood. The grasshoppers harm the harvest. The optimal solutions and decisions of problems achieved through applying this algorithm. The algorithm has good classification accuracy. There are various variants that have been implemented for Grasshopper optimization due to easily modifiable features of the algorithm, that is why it's more flexible and scalable in solving problems. It cannot be applied to any optimization problem because Grasshopper reaches quickly to the comfort zone. The GHO easy to fall into local optimum. The algorithm has less capability of tackling search processes in different ways of inputs. Every iteration step gives different results conferring to statistical analysis.

**2.6. Dragon Fly Algorithm**

It is a meta heuristic, swarm optimization inspired algorithm. The dragonflies reproduced the eggs in water. The dragonflies also have newbie and adult stages like grasshoppers. Dragonflies are expert filers; they can fly up, down, back, and forth in any direction. For the sourcing of food, dragonflies perform explore and exploit search. The dragonflies keep distant far away from enemies. When the search area is large, dragonflies need low adjustments and high cohesion while if the search area is small, they need high adjustments and low cohesion to grasp the static prey. The dragonflies are capable enough to seek prey in large areas as well. The algorithm convergence rate is good and better for global optimum. There are very few chances to easily fall in local optimum. There are very few parameters required for implementation of the dragonfly algorithm. It has no standard model for implementation, and can be easily done in different ways. The DA outperforms efficiently. The DA may have too early convergence that is not good. There are various variants that have been implemented for DA due to reliable features of the algorithm that is the reason that it is more flexible and scalable in solving problems.

**2.7. Particle Swarm Algorithm**

The swarm particle moves like a sine wave motion. It does not ensure convergence for even global optima, the adopted procedures stuck in individual optima due to lack of diverse population of swarm particles. The solution of particle swarm optimization falls in local optimum at lower extreme values that is not good and avoidable. It suffers from premature convergence. The particle swarm is not cooperative in searching problems. It is based on the moment & intelligence of swarms. Several swarm particles communicate either directly or indirectly with one another using search directions. During an iteration of PSO, each particle updates its position according to its previous experience and the experience of its neighbours.. The PSO does not implement survival of the fittest strategy. In the fitness function, it shows that it is trapped at local minima.

**2.8. Harris Hawks Optimization Algorithm**

It follows a swarm-based optimization method. The hawks are smart birds that fly in the sky. They have cooperative behaviour. The way of hunting by hawks is very strange. The hawks perform exploration and exploitation search. They always keep eyes and wait for the hunt, and as soon as they see, pounce on them quickly. HHO works as a better solution optimizer. The main idea is to mimic the action and reaction of Hawk's team collaboration hunting in nature & prey escaping to discover the solutions of the single objective problem. The HHO always converge to global optimum. This algorithm gets trapped in local optimum and immature convergence.

**2.9. Bald Eagle Search Algorithm**

The word bald mean is white and bald eagle is the national bird of U.S.A. The bald eagle hunts the fishes. The way of considering the prey is very similar to HHO. The bald eagle first chooses the domain, second, they search food in specific domain and if they found the prey, swooping it. The BES algorithm works like the combination of evolutionary intelligence and particle swarm. First they select seek point, after they search food around a centre point of specific domain. The research paper says that highly blowing air, storms, force of gravity gives more convenient and appropriate environment to hunt the prey easily without consuming more energy. The BES has fast convergence speed over HHO. The BES algorithm obtains the best results and its performance is extremely different from that of other algorithms. The localization areas are very big, that is why to attain the global optimization complex compared with other functions. The BES also work with integration of another optimizer algorithm. For predicting continuous values of parameter, support vector regression (SVR) methodology is used in many areas of machine learning. The SVR method is optimized by GWO with BES for achieving the prediction and accuracy of convergence.

**2.10 Comparative Table**

| Algorithm | Working | Advantages | Disadvantages | Proposed By |
|---|---|---|---|---|
| Cuckoo Search (CSO) | The cuckoo species are always moving for some cuckoo species lay their eggs in the nests of host birds if discovers the eggs are not their own eggs, either throw or simply abandon nest and build a new nest elsewhere. It is a metaheuristic algorithm.<br><br>It possess randomized move in all dimensional spaces which give global optimal solution. | CSO is used in estimating the parameters of software reliability growth model. It solves Nurse scheduling problem, Travelling salesman problem, knapsack problem and training neural network.<br><br>CSO works better than PSO. | It provides the local optimal solution and the slow rate of convergence. | Yang & Deb (2009) |
| Firefly | This algorithm based on unique flashing patterns, nature inspired metaheuristic, swarm intelligence and behaviour of fireflies.<br>The fireflies moved or walked due to the attraction of light intensity of each other for communication.<br>The light intensity represents their fitness function.<br>The decrease in distance between two fireflies seems if their brightness of light is low. It means the brightness of fireflies are inversely proportional to distance among them.<br>The fireflies of lower intensity approach towards higher intensity.<br>The fireflies move randomly If they have the same intensity or brightness.<br>The new position of fireflies was achieved by the random walk and communication of them. | • Used for Non-linear optimizatio n problems<br>• Solves dynamic problems<br>• In fault detection<br>• In feature selection<br>• In antenna design based problem<br>• It works better than optimal intermittent search.<br>• It works for high dimensioal optimizatio n problem due to metaheurist ic nature.<br>• It works for travelling salesman problem. | This algorithm has a few disadvantages in the global searching including slow convergence speed & high possibility of being trapped in local optimum. | Xin-She Xang (2008) |

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| | The random walk done in steps. This algorithm is applicable in various engineering domains like solving nonlinear optimization problems, fake detection, feature selection, dynamic programming problems, antenna design, structural design etc. Due to the attraction method of fireflies, it has a speedy convergence rate for global optimum but it lacks for local optimum. | | | |
| Ant Colony (ACO) | This is a metaheuristic algorithm based on Particle Swarm Optimization (PSO) to find approximate solutions of difficult optimization problems. All ants are in their nest. Ants begin their search with equal probability along each path. The ants through the shorter path reaches food source earlier. Finds the best, fastest and shorter routes. | • To apply Ant colony algorithm, the optimization problem is transformed into the problem of finding the best path on a weighted graph.<br>• Travelling salesman | Theoretical analysis is difficult. Sequences of random decisions (not independent) Probability distribution changes by iteration. Research is experimental rather than theoretical. Time to convergence uncertain but convergence is guaranteed. | Dorigo et al (1996) |
| Grey Wolf (GWO) | Th The algorithm is inspired by the hunting strategy of grey wolf. The Grey wolf (GW) lives in a pack or group of 5-12 packs. They can work together in a pack. There is a pack leader. The pack waits for the prey to enter their territory. The hunting done in different ways are called Alpha, beta, delta, and omega respectively. They(wolves) search for the prey by themselves. Select weakest prey. They hunt in a cooperative way. The algorithm with the decision tree helps to analyse genome data in cancerous cells. The algorithm works for image enhancing. The Grey wolf gives low solving accuracy, bad local searching ability and slow convergence rate. The main drawback of GWO is the low capability to handle the difficulties of a multi-modal search landscape, as it seems that all three alpha, beta and gamma wolves tend to converge to the same solution. Adding more random components | • The GWO is used to solve different problems such as global optimization problems, electric & power engineering, scheduling problems, power dispatch problems, control engineering problems, robotics & path planning problems, environmental planning problems & many others. Used in implementation of open source software (LabVIEW), libraries, frameworks & toolboxes of GWO. | • Low solving accuracy.<br>• Bad local searching ability.<br>• Slow convergence rate.<br>• The main drawback of GWO is the low capability to handle the difficulties of a multi-modal search landscape, as it seems that all three alpha, beta and gamma wolves tend to converge to the same solution.<br>• Adding more random components to mutate the solutions during optimization will increase the chance of finding a global optimum when solving challenging multi-model problems. The GW optimization achieved due to three types of implementations are seek, encroachment and attack over the prey. [12] For predicting continuous values of parameter, support vector regression(SVR) methodology is used in many areas of machine learning. The SVR method is optimized by GWO with BES for achieving the prediction and accuracy of convergence. | Mirjalili et al (2018) |
| Grasshopper (GOA) | This metaheuristic algorithm comes under the category of swarm intelligence behaviour and Inspired by foraging. The grasshopper is a bug found in the natural, open environment and mostly in the fields of farmers. It is born from an egg and has two stages, in the first stage it lies inside a nymph and in the second stage reaches adulthood. The grasshoppers harm the harvest. The optimal solutions and decisions ofroblems achieved through applying this algorithm. The algorithm has good classification accuracy. There are various variants that have been implemented for Grasshopper optimization due to easily modifiable features of the algorithm, that is why it's more flexible and scalable in solving problems. The GHO easy to fall into local optimum. The algorithm has less capability of tackling search processes in different ways of inputs. In every step of iteration, the algorithm gives different results according to statistical analysis. | • Obtain better solution as compared to other meta huristic algorithm.<br>• High accuracy.<br>• It is inspired by foraging and swarming behavior. | It cannot be applied to any optimization problem because Grasshopper reaches quickly to the comfort zone. | Saremi and Mirjalili (2017) |
| Dragonfly | It is a metaheuristic, swarm optimization inspired algorithm. The dragonflies reproduced the eggs in water. | • Algorithm inspired by the static and dynamic behavior of dragonflies. | • Levy Flight Mechanism (LFM) has disadvantages such as | Mirjalili (2016) |

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| | It is a metaheuristic, swarm optimization inspired algorithm. The dragonflies reproduced the eggs in water. The dragonflies also have newbie and adult stages like grasshoppers. Dragonflies are expert filers; they can fly up, down, back, and forth in any direction. For the sourcing of food, dragonflies perform explore and exploit search. The dragonflies keep distant far away from enemies. When the search area is large, dragonflies need low adjustments and high cohesion while if the search area is small, they need high adjustments and low cohesion to grasp the static prey. There are very few chances to easily fall in local optimum. There are various variants that have been implemented for DA due to reliable features of the algorithm, that is why it's more flexible and scalable in solving problems. Dragonflies are expert filer they can fly in up down, back and forth in any direction. | • The random flying behaviour of dragonflies in nature is modeled in the dragonfly algorithm using the Levy Flight Mechanism(LFM).<br>• The static & dynamic behavior of dragonflies are feeding swarm and migration respectively.<br>The dragonflies are capable enough to seek prey in large areas as well.<br><br>The algorithm convergence rate is good and better for global optimum.<br><br>There are very few parameters required for implementation of the dragonfly algorithm. It has no standard model for implementation, and can be easily done in different ways.<br><br>The DA outperforms efficiently. | the overflowing of the search area & interruption of random flights due to its big searching steps.<br>The DA may have too early convergence that is not good. | |
| Particle swarm Optimization (PSO) | It is an evolutionary and stochastic optimization technique to solve computationally hard optimization problems.<br>It is based on moment & intelligence of swarms. A swarm of n particles communicate either directly or indirectly with one another using search directions(gradients). During an iteration of PSO, each particle update its position according to its previous experience and the experience of its neighbors. | • It can be applied to a wide variety of search & optimization problems.<br>• Method works in different situations. | • PSO does not implement survival of the fittest strategy.<br>• In rastrigin fitness function, it shows stuck at local minima. | Kennedy & Eberhart (1995) |
| HHO (Harris Hawks Optimization) | Swarm based optimization method.<br>Main idea is to mimic the action & reaction of Hawk's team collaboration hunting in nature & prey escaping to discover the solutions of the single objective problem. | • Explore, exploit, attack.<br>• HH hunts randomly on certain areas & wait to detect prey.<br>• They check the position of other family members and target position. | • Not always converge to global optimum.<br>• The possibility of being trapped in local optimum and immature convergence. | Heidari et al(2019) |
| BES | • Select stage<br>• Search stage<br>• Swooping stage<br>• It has fast convergence speed over HHO. | BES algorithm obtains the best results and its performance is extremely different from that of other algorithms. | Localisation areas is extremely large, which makes approaching global optimisation difficult compared with other functions. | H.A. Alsattar et al |

**3, Conclusion and Discussions**

The nine optimized algorithm are studied and examined in different studies. It was found that all the studies are carried out in different dataset by different researchers. All the algorithm can be used as implementation and studied as a research. All the algorithm has its advantage to use and implemented.

This study can be further studied by implementing the algorithm at a single dataset. The comparative study will provide the performance and be used as an implementation as an application of perspective analytics and an application of Machine Learning techniques.

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